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Resistance of Acetylated Wood to Attack by Subterranean Termites*

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Abstract——Softwood veneers treated with acetic anhydride, in the presence of sodium acetate as a catalyst, were found to be resistant of attack by subterranean termites. *Coptotermes formosanus* was able to attack acetylated wood, but loss in volume of the wood decreased according to the increase of weight gain during acetylation. Acetylated wood was hardly ingested by the other kind of termite, *Reticulitermes speratus*. Resistance of acetylated wood was assumed to be due to the inability of symbiotic protozoa to utilize wood as a result of stable chemical bonds in water-accessible regions of the cell wall components.

1. Introduction

Chemical modification of wood has been examined to impart biological resistance and to increase dimensional stability by obtaining an adequate distribution of reacted chemicals in the water-accessible regions of wood cell walls. Chemicals those have been used to modify wood include anhydrides, acid chlorides, isocyanates, lactones nitriles, epoxides, inter alia[1].

Wood modification techniques are currently receiving interest for the prevention of biodeterioration. Because of the toxicity of conventional wood preservatives, they are the subject of growing environmental concern. Efforts to develop non-toxic methods for preserving wood have been intensified all over the world. Chemical modification of wood is potentially a good alternative to conventional wood preservation[1,2]. One such modification system, which has received considerable attention, is acetylation.

A number of studies on wood acetylation have been reported in the past, and the acetylated wood is said to have excellent physical and biological properties, such as those related to dimensional stability, and resistance to decay and termite attack[3]. Wood acetylated to a weight-gain above 17 percent has been found to be resistant

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to attack by decay fungi; resistance to attack from the termite *Reticulitermes flavipes,* was obtained at higher weight gains from acetylation[4].

The present study was carried out to evaluate the resistance of acetylated wood against attack by two kinds of subterranean termites indigenous to Japan.

2. Materials and Methods

2.1 Materials

3 mm-thick rotary veneers of Spruce (*Picea jezoencis* Carr.), Larch (*Larix leptolepsis* Gord.) and Douglas-fir (*Pseudotsuga menziesii* Franco), which were of relatively poor durability, were used for production of acetylated specimens.

The veneers were oven dried and impregnated with sodium acetate as a catalyst. The samples were again oven dried, and after which transferred to a stainless steel vessel and impregnated with acetic anhydride. Acetylation was carried out for a required period (30 to 60 minutes) at 120–130°C. Then, after unreacted acetic anhydride and the by-product acetic acid were recovered, reacted veneers were rinses in water until the smell of acetic acid was removed. The veneers were then dried with hot air. The acetylated veneers were obtained at percent weight gain (observed acetylation rate) of 20 percent for Spruce and Douglas-fir, and 7, 12 and 20 percent for Larch.

To form acetylated and untreated LVLs, a adhesive of resorcinol resin was spread at the rate of 200 grams per square meter, and LVLs were hot-pressed at 8 kilograms per square centimeter and 110°C.

The procedure of wood acetylation described above was recently develped in Daiken Trade &Industry Co., Ltd. for the manufacture of acetylated wood on an industrial basis[5].

2.2 Test methods

Specimens used for termite resistance tests were $20 \times 20 \times 20$ mm cubes of LVLs with all layers acetylated and contrlos of LVLs untreated. Six layers of veneers were laminated for each specimen.

For evaluation of termite resistance, two test methods were employed. A forced feeding test was used where treated or untreated wood was the only source of nutrient for the termites according to the Japan Wood Preservation Association Standard (No. 11, 1981). The individual test specimen together with 150 sound workers and 15 soldiers were put in a cylindrical, clear plastic container (inside dimensions, 8 cm in diameter and 6 cm in height) having the bottom sealed with hard plaster of Paris. The plastic containers were placed in a large covered case which had moist cotton wool at the bottom to keep the test sets in high humidity condition. After a 21 days test duration, the number of dead termites was recorded. The test specimens were then removed, cleaned down surface debris and adherent material by washing, and subsequently oven dried (60°C) and weighed. The percentage weight loss of the specimens was caluculated

The other method was a choice feeding test in which specimens were placed randomly on the breeding nest of termites for a period of 30 days. Percent weight loss was caluculated in the same manner as described above. Two termite species, *Coptotermes formosanus* Shiraki and *Reticulitermes speratus* Kolbe, which have been causing severe damages to housing-materials in Japan, were employed for the tests.

3. Results and discussions

The decay resistance of acetylated wood used in this study has previously been evaluated[6]. Larch acetylated at rates of 7 and 12 percent allowed very low loss in weight when exposed to attack by *Coriolus versicolor* and *Tyromyces palustris*, respectively. Specimens of any wood species of Larch, Spruce and Douglas-fir, acetylated at a rate of 20 percent showed high resistance to decay. Those results are indicative of the very low susceptibility of acetylated wood to attack by decay fungi.

As shown in Tables 1 and 2, and Fig. 1, all acetylated specimens of Spruce, Larch and Douglas-fir were superior to untreated specimens in limiting ingestations of both *C. formosanus* and *R. speratus*. Although *C. formosanus* was able to attack acetylated wood, loss in volume of wood was significantly small when compared with untreated wood. At higher weight gain from acetylation, the termites digested lesser wood, and there seems to be a correlation between the acetylation rate and the weight loss by termite infestation. The termite, *R. speratus* could hardly attack ace-

Table 1. Resistance of acetylated wood against subterranean termites of *C. formosanus**

Wood species	Treatment	FT		CT
		Weight loss (%)	Mortality (%)	Weight loss (%)
Spruce	untreated	10.5	10	77.7
	acetylated (20%)**	6.9	44	30.4
Larch	untreated	8.4	12	47.9
	acetylated (7%)**	6.9	28	26.2
	acetylated (12%)**	6.7	38	24.3
	acetylated (20%)**	4.2	47	13.9
Douglas-fir	untreated	8.4	9	66.7
	acetylated (20%)**	5.7	41	13.2

*: mean value of five replicates. **: observed weight gain by acetylation.
FT: forced feeding test. CT: choice feeding test.

Table 2. Resistance of acetylated wood against subterranean termites of *R. speratus**

Wood species	Treatment	FT		CT
		Weight loss (%)	Mortality (%)	Weight loss (%)
Spruce	untreated	12.8	9	75.0
	acetylated (20%)**	0.8	100	1.3
Douglas-fir	untreated	10.2	12	63.8
	acetylated (20%)**	0.3	100	0.6

*: mean value of five replicates. **: observed weight gain by acetylation.
FT: forced feeding test. CT: choice feeding test.

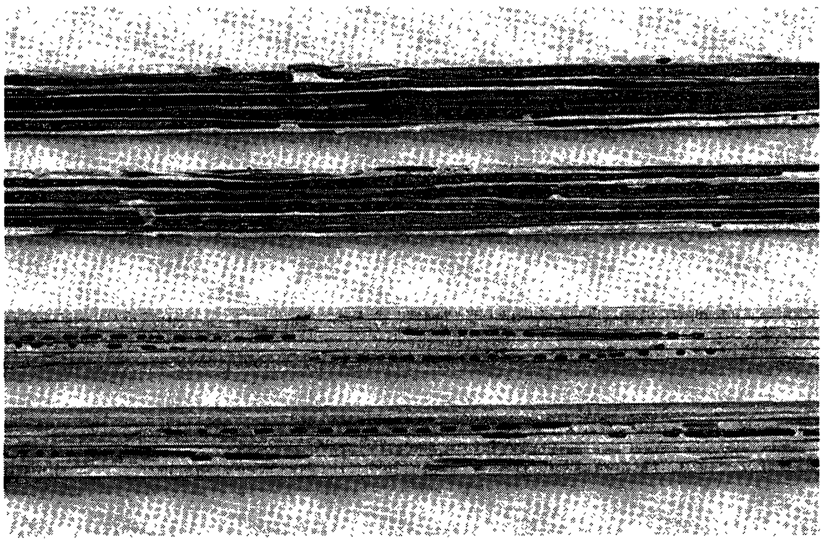

Fig. 1. Untreated and acetylated Douglas-fir LVLs exposed to attack by termites of *C. formosanus* for 30 days on the breeding nest. Size of specimen is 20×20×300 mm.

tylated wood leaving only marks of nibbling.

In the control sets of the force feeding tests, the termites survivals were over 90 percent both for *C. formosanus* and *R. speratus*; the matching percentages for acetylated specimens were below 60 percent, and 0 percent, respectively. This shows that the acetylation of wood caused greater mortality of *R. speratus* than of *C. formosanus*. The mortality was not marked until the two week inspection for *C. formosanus* and the one week inspection for *R. speratus*, but it increased at later inspections indicating a slow-acting toxic action or an enhanced starvation effect. As the acetate groups that reacted with wood should not theoretically be toxic to termites, the resistance of modified wood seems attributable to its unpalatability to the termites.

It is of interest that there was a great difference between infestations of acetylated wood by the above two termites. This could have been expected because some insecticides take different effects to attacking termites. For example, *Coptotermes niger* and *Heterotermes tenuis* were shown to be heavier and more aggressive feeders than *Reticulitermes flavipes* against wood treated with chlordane or some other chemicals[7].

To examine the effect of wood acetylation to termite activities, three types of Spruce veneers (3 mm-thick) were prepared; the first one being acetylated at 20 percent weight gain (A), the second one being an untreated control (U), and the third one being untreated but impregnated with acetic acid (UA). Each of the veneer specimens (2.5×2.5 cm) were put in plastic containers in the same manner as the forced feeding test described above. Containers without wood specimens were also used for starvation datum (S). Groups of 50 workers of *C. formosanus* or *R. speratus* were placed in each such sets for counting the number of those which died with time. Fig. 2 shows the average results of these tests which were repeated three times.

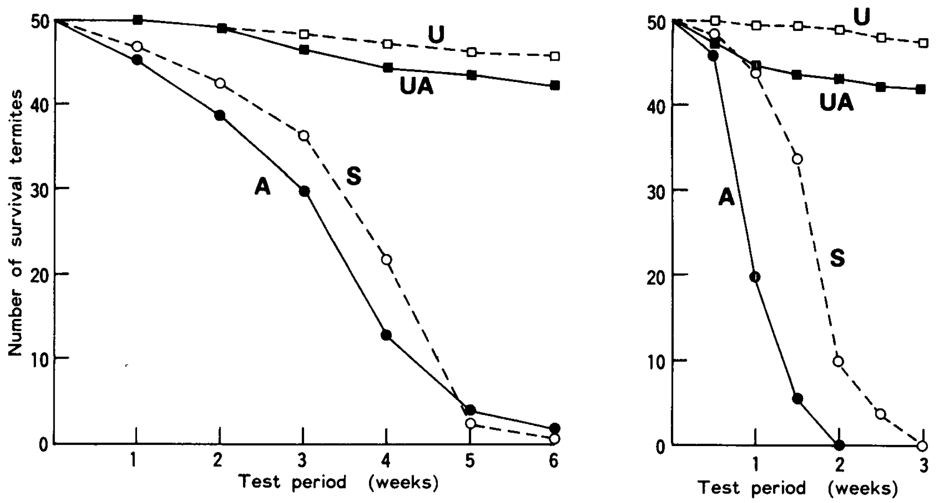

Fig. 2. The number of survival termites in rearing with untreated wood (U), untreated but impregnated wood with acetic acid (UA), acetylated wood (A), and in starvation (S).

In sets UA as well as in sets U, few death were recorded within test period. From this, it may be said that the effect of acetylation against termites is produced not by the residual acetic acid in the acetylation process, but by the acetylated wood itself that affects the digestive system of termites.

In sets A, almost all termites of *C. formosanus* and *R. speratus* died after 5 weeks and 10 days respectively, while mortality of termites in the control sets was significantly small even after each test period. The number of survival termites of both sets A and S decreased in a similar manner, showing that acetylation may have merely enhanced the starvation effect. However, the survival termites in sets A were comparatively fewer than those in the empty sets S, especially for *R. speratus,* all termites in sets A died one week earlier than in sets S. This may indicate, as shown in the termite test on alkylene-oxide modified wood[8)], that the energy expended to eat the treated wood was not balanced by the nutritional energy obtained from the wood, thereby having a slightly harsher starvation effect than the mere absence of wood in the straved sets.

Changes of protozoan fauna in the intestines of the workers can also be used

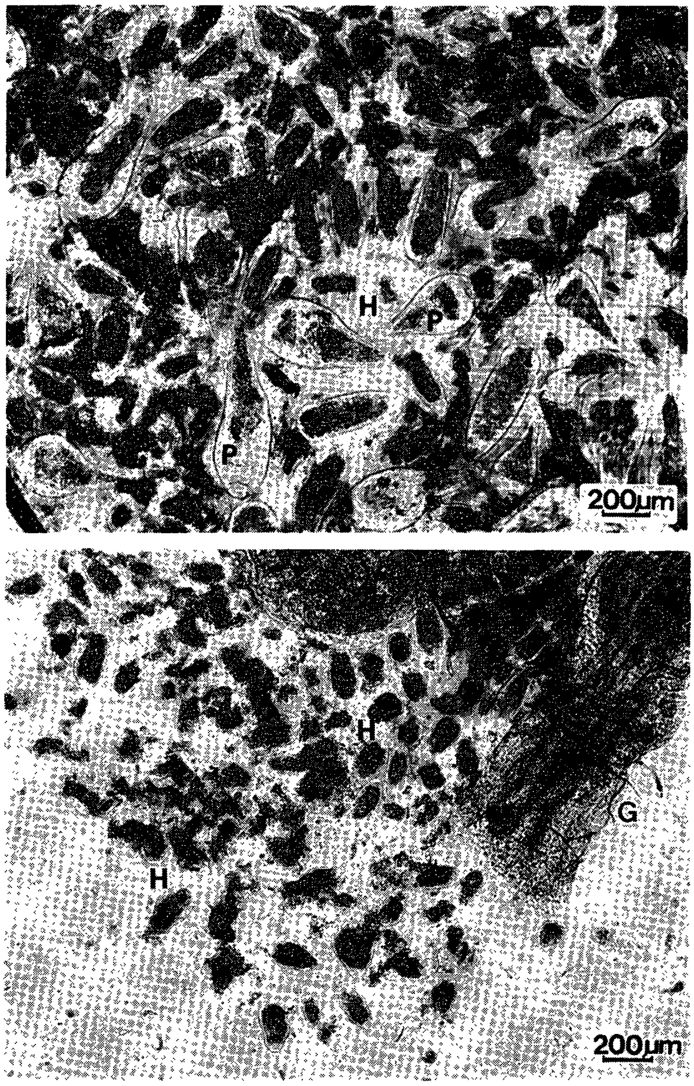

Fig. 3. Intestinal protozoa fauna of *C. formosanus* reared with untreated (upper) and acetylated wood (lower). P: *Pseudotrichonympha grassii,* H: *Holomastigotoides hartomanni,* G: gut.

for clarifying the effect of acetylation. The survival termites of *C. formosanus* reared with acetylated wood and untreated wood for one week were compared to examine the changes of the protozoa after squahsing out their hindguts (Fig. 3). Three kinds of protozoa, *Pseudotrichonympha grassii, Holomastigotoides hartmanni* and *Spirotrichonympha leidyi* were found to be present in the sound termites. In the intestine of the termite reared with acetylated wood, the number of protozoa decreased greatly and the largest forms of the protozoa, *P. grassii,* disappeared completely. The change of protozoa fauna is similar to that of starving termites as shown by Kanai et al.[9]

Although the digestive system of termits has been poorly understood, symbiotic protozoa are said to play a great role in it. It has been pointed out that cellulose in wood may be at first partially decomposed by the protozoa *P. grassii* in the intestine of the termite, *C. formosanus*[9]. Acetylated wood is eaten by the termites and taken into their intestines, but it is not decomposed by the symbiotic protozoa. As a result, the termites cannot obtain nutrient from the breakdown of the wood and are unable to remain alive if no other nutrient exist.

Goldstein et al. have pointed out that acetylated wood was resistant to wood-decay fungi at a weight gain of about 17 percent[4]. Their paper, as well as the present study, showed that loss of wood volume caused by termite attack indicated an apparent threshold at 17 and 20 percent value for acetylation. It is of interest that cell wall decomposition by fungi and utilization of wood by the symbiotic protozoa of termites hardly occur if wood has been acetylated at the rate of 20 percent above. This is considered to be due to the specific biological degradation which is common to both of them.

Another possible explanation for the resistance to termite attack exists in the increased hardness of the modified wood. It was already noted that acetylated wood prepared for this study was almost equivalent in strength to original wood, while wet strength of acetylated wood increased[5]. Subterranean termites can carry water to attacking wood, but acetylated wood absorbs little water and is considered to be harder for biting than untreated wood which attracts more moisture and causes dimensional increase. The change in physical properties by acetylation seems not to be a major reason at least for explaining the resistance to attack by *C. formosanus,* but it may be of improtance for *R. speratus* which are unable to bite the treated wood.

To determine the termite resistance of acetylated wood in field exposures, tests on treated LVLs of large dimensions have been in progress in the termite test site in Kagoshima Prefecture.

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